

the housing chamber through the opening to ensure that the casing chamber and the housing chamber collectively define a vacuum chamber. The driving shaft is accommodated in the vacuum chamber to be operatively connected at one end with the handling mechanism disposed in the casing chamber and at the other end with an electric motor disposed in the housing chamber. The handling mechanism includes a handling member pivotally supported by the driving shaft to be operative to handle wafers and other substrates in the casing chamber.

The conventional shaft sealing apparatus thus constructed, however, encounters such a problem that the conventional shaft sealing apparatus is complicated in construction and thus increased in size, resulting from the fact that the conventional shaft sealing apparatus is required to comprise a shaft housing axially movably connected with the vacuum casing through the bellows unit.

The conventional shaft sealing apparatus described in the above encounters another problem that the exhaust load of the vacuum chamber is increased, resulting from the fact that the vacuum chamber is increased in space to have the driving shaft, the electric motor and other parts accommodated in the vacuum chamber.

The conventional shaft sealing apparatus described in the above encounters further problem that dust particles generated from the driving shaft, the electric motor and other parts are discharged into the vacuum chamber, resulting from the fact that the driving shaft, the electric motor and other parts are accommodated in the vacuum chamber.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a shaft sealing apparatus that is excellent in characteristic to seal the gaps between a driving shaft and other parts around the driving shaft.

It is another object of the present invention to provide a shaft sealing apparatus that can be simple in construction and thus reduced in size.

It is further object of the present invention to provide a shaft sealing apparatus that can be assembled with facility.

In accordance with a first aspect of the present invention, there is provided a shaft sealing apparatus, comprising: a vacuum casing formed with a vacuum chamber; a driving shaft having an outer cylindrical surface and movably extending in the vacuum chamber of the vacuum casing; and a sealing ring in the form of an annular ring shape and including a sealing lip held in contact with the outer cylindrical surface of the driving shaft, an annular spring member operative to impart a force to the sealing lip to ensure that the sealing lip is held in tight contact with the outer

cylindrical surface of the driving shaft, and a peripheral portion radially outwardly extending from the sealing lip, in which the outer cylindrical surface of the driving shaft is smaller in surface roughness Ra than $0.1 \mu\text{m}$.

5 The outer cylindrical surface of the driving shaft may be larger in Vickers hardness Hv than 650.

The annular spring member of the sealing ring may be made of a metal wire in the form of a helical shape and is of a circular cross-section taken on the plane perpendicular to the center axis passing therethrough.

10 The annular spring member of the sealing ring may be made of a metal plate in the form of an annular ring shape and is of a channel-shaped cross-section taken on the plane perpendicular to the center axis passing therethrough.

The sealing lip of the sealing ring may be made of a synthetic resin constituted by an ultra high molecular weight compound.

15 In accordance with a second aspect of the present invention, there is provided a shaft sealing apparatus, comprising: a vacuum casing formed with a vacuum chamber and having a base portion formed with an opening to have the vacuum chamber of the vacuum casing held in communication with the atmosphere through the opening of the vacuum casing; a shaft housing in the form of a cylindrical hollow shape and fixedly connected with the base portion of the vacuum casing, the shaft
20 housing having an inner cylindrical surface; a driving shaft in the form of a cylindrical shape and received in the shaft housing to be movably supported by the shaft housing, the driving shaft held in coaxial alignment with the shaft housing and having a first axial end extending in the vacuum chamber of the vacuum casing, a second axial end extending in the atmosphere, and an outer cylindrical surface smaller in diameter than
25 the inner cylindrical surface of the shaft housing; and a sealing unit received in the opening of the vacuum casing and fixedly supported by the base portion of the vacuum casing, the sealing unit including a retaining member in the form of an annular ring shape and fixedly connected with the base portion of the vacuum casing, and a sealing ring in the form of an annular ring shape and securely retained by the
30 retaining member of the sealing unit, the sealing ring of the sealing unit intervening between the driving shaft and the retaining member of the sealing unit to hermetically seal the gap between the driving shaft and the retaining member of the sealing unit, the sealing ring of the sealing unit including an annular resilient member formed with an annular groove, and an annular spring member received in the annular groove of
35 the annular resilient member and retained by the annular resilient member, the annular resilient member of the sealing ring having a peripheral portion securely retained by the retaining member, and a sealing lip integrally formed with the peripheral portion

of the annular resilient member and radially inwardly extending from the peripheral portion of the annular resilient member to be held in contact with the outer cylindrical surface of the driving shaft, the annular spring member of the sealing ring operative to impart a force to the sealing lip of the annular resilient member to ensure that the sealing lip of the annular resilient member is held in tight contact with the outer cylindrical surface of the driving shaft.

In accordance with a third aspect of the present invention, there is provided a shaft sealing apparatus, comprising: a vacuum casing formed with a vacuum chamber and having a base portion formed with an opening to have the vacuum chamber of the vacuum casing held in communication with the atmosphere through the opening of the vacuum casing; a shaft housing in the form of a cylindrical hollow shape and fixedly connected with the base portion of the vacuum casing, the shaft housing having an inner cylindrical surface; a sleeve shaft in the form of a cylindrical hollow shape and received in the shaft housing to be movably supported by the shaft housing, the sleeve shaft held in coaxial alignment with the shaft housing and having a first axial end extending in the vacuum chamber of the vacuum casing, a second axial end extending in the atmosphere, an outer cylindrical surface smaller in diameter than the inner cylindrical surface of the shaft housing, and an inner cylindrical surface; a center shaft in the form of a cylindrical shape and received in the sleeve shaft to be movably supported by the sleeve shaft, the center shaft held in coaxial alignment with the sleeve shaft and having a first axial end extending in the vacuum chamber of the vacuum casing, a second axial end extending in the atmosphere, and an outer cylindrical surface smaller in diameter than the inner cylindrical surface of the sleeve shaft; a first sealing unit provided on the first axial end of the sleeve shaft and held in coaxial alignment with the sleeve shaft, the first sealing unit including a retaining member in the form of an annular ring shape and fixedly connected with the first axial end of the sleeve shaft, and a sealing ring in the form of an annular ring shape and securely retained by the retaining member of the first sealing unit, the sealing ring of the first sealing unit intervening between the center shaft and the retaining member of the first sealing unit to hermetically seal the gap between the center shaft and the retaining member of the first sealing unit, the sealing ring of the first sealing unit including an annular resilient member formed with an annular groove, and an annular spring member received in the annular groove of the annular resilient member and retained by the annular resilient member, the annular resilient member of the sealing ring having a peripheral portion securely retained by the retaining member, and a sealing lip integrally formed with the peripheral portion of the annular resilient member and radially inwardly extending from the peripheral portion of the annular